Strengths of Educational Resources for Instruction in Higher Education

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Introduction

With an onslaught of many new technologies and new uses of technology in education to provide alternative methods for instructing students, many educators were left wondering when it is appropriate to use technology for instruction in higher education. A slew of research suggests the circumstances under which technology improves, maintains, or even hurts learning outcomes, but many of these studies compare the new method of instruction to a "traditional" method in which a lecturer talks at students during class time, holds office hours, and provides little additional support. The problem with this type of comparison is that many other non-technological interventions are available to improve upon the "traditional" method, so while the technological method might be an improvement, it is not necessarily the best method.

Now that technological resources are more commonly used at universities to provide online instruction to on-campus students, educators are asking under what circumstances it is best to use technology and when it is best to rely on peer interactions and instructors. Research on successful uses of technology, peers, and instructors in education is abundant, but direct comparisons between these use cases are uncommon. This report analyzes the successful cases from this literature and inductively determines the strengths of these educational resources. Then this report integrates this information to predict how educational resources could be best applied in courses. Though a meta-analysis would be preferable, predictions about which resource is better than another for a specific function in education (e.g., whether technology or peers are better at providing constant, instant feedback) are all that can be supported without additional research. Pressing research questions on the effective use of these educational resources are also identified.

The Strengths of Technology

In general, technology serves to make tasks easier, faster, or more feasible by changing the method with which we do things, though not the purpose of the task. Similarly, technology in higher education does not change learning but supports learning through different methods. Higher education institutes increasingly use information communications technologies (mainly computers) for their pedagogical, accessibility, and flexibility benefits (Bonk & Graham, 2005). For decades, technology has been used to improve pedagogy in traditional face-to-face instruction by enhancing organization (e.g., through learning management systems), providing resources (e.g., online discussion forums or virtual tutors), and supplementing instruction (e.g., with audiovisual instructional materials). A meta-analysis of 40 years of research on the impact of technology on learning found that students performed on average 12% better in classrooms supplemented by technology than classrooms without technology (Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011). During this time, technology was also used to deliver instruction to distance learners, and more recently online learners, to increase the accessibility and flexibility of higher education programs for those unable or unwilling to attend on-campus classes. The lists below suggest how technology can be leveraged to improve higher education.

Technology allows for cost-effective learning at scale by

- Affording automatic/participation and machine grading for multiple choice, closed-ended, and sometimes open-ended summative assessments (Fox, 2013)
- Distributing information and domain content to an unlimited number of people (Yang, 2012; Nielsen, 2011; Walsh, 2011)
- Reducing required class time by providing content online (Walsh, 2011)
- Accommodating more students through online content and open resources (Walsh, 2011)
- Easing access to vetted sources of information (Ellmore et al., 1995; NSF-CRA, 2013; Williams, 2005; Daniel, 2012; Walsh, 2011; Oliver, 2001)
- Providing consistent instruction and support regardless of factors of the instructor or student, such as illnesses, personal issues, biases, etc. (Ellmore et al., 1995; NSF-CRA, 2013; Atkinson & Derry, 2000; Lowe & Holton, 2005)
- Teaching content that would be categorized in the lower levels Bloom's taxonomy as effectively as an instructor (Oliver, 2001)
- Supporting individual student paces for mastery-based learning (Reimann et al., 2012)
- Providing resources and feedback on quantitative problem solving practice (Crouch & Mazur, 2001)

Technology can use big data to make well-informed recommendations for students by

- Collecting big data about instruction and assessments (Fox, 2013; Bonvillian & Singer, 2013)

- Using big data to develop machine learning (Bonvillian & Singer, 2013)
- Analyzing large amounts of up-to-date data unbiasedly (NSF-CRA, 2013; Lowe & Holton, 2005)
- Identifying common misconceptions and knowledge gaps and provide remediation (Khan, 2012)

Technology allows for flexibility and personalization by

- Being accessible 24/7/365 (Fox, 2013), though it also needs technical support.
- Enabling virtual interactions regardless of distance (Fowler, 2013) to connect students to other students with similar interests or advanced/specialized teachers (Khan, 2012)
- Being flexible on time, place, pace, and sometimes style of instruction (Khan, 2012; Lowe & Holton, 2005; Walsh, 2011; Fowler, 2013; Twigg, 2003)
- Provide additional support to refresh prior knowledge or prerequisite knowledge (Nielsen, 2011)
- Personalizing content (either by changing the difficulty or representations and examples) to maximize learning by enabling access to various instructional resources (NSF-CRA, 2013; Williams, 2005; Daniel, 2012; Knowles et al., 2011)

Technology can provide learning experiences that would not otherwise be reasonable or even possible by

- Supporting simulations (Lowe & Holton, 2005) and increasing realism of simulations (NSF-CRA, 2013; Walsh, 2011)
- Providing convenient interactive experiences with other students outside of the classroom (Ellmore et al., 1995)
- Enhancing instruction and learning outcomes with multimedia presentations, animations (Tamim et al., 2011), and interactive resources (Walsh, 2011)
- Mimicking human interaction and mentorship through the use of animated pedagogical agents and intelligent tutoring systems (Bowman, 2012; Atkinson, 2002)
- Making global perspectives available (Daniel, 2012)
- Giving instant feedback (Twigg, 2003)

Drawbacks of Technology

- Needs technical support
- Requires training and comfort of use
- For people uncomfortable or unfamiliar with the technology, uses cognitive resources to operate

The Strengths of Peers

In the past several years, the focus for advancing higher education has been on technology, particularly for providing higher education at a mass scale without increasing the number of instructors. A similar movement started in the 1800s with peer instruction. Though the affordances of technology lend themselves to improving the accessibility and convenience of education, personal interaction is important in education for exchanging ideas and motivating students (Goldschmid & Goldschmid, 1976). If we want to provide this interaction at a mass scale, then we need to get peers working together (Fowler, 2013).

Peer learning can be implemented in many different ways. One implementation is reciprocal teaching in which students learn about different topics and teach each other. Reciprocal teaching asks students to cover domain content instead of the instructor (or allows students to pursue topics that interest them) and provides an opportunity for students to practice communication skills (Goldschmid & Goldschmid, 1976). For example, for a history class, students can research a historical event (either assigned to them or picked by them) and present that information to the class. This type of peer learning would help the student develop their presentation skills and allow the instructor to be in an intervener role rather than an explainer role.

In another type of peer learning, students learn about the same topic and discuss the concepts to check for understanding. For example, for an art course, students can individually analyze a piece of art then discuss their analyses to hear others' ideas and receive feedback on their own. This type of peer learning would help students understand different perspectives and develop their understanding further. Another method of peer learning pioneered by Eric Mazur, called Peer Instruction (PI), has demonstrated that working in peer pairs on conceptual problems is correlated with better quantitative problem solving performance in areas like physics (Crouch & Mazur, 2001).

Peer assessment is another implementation of peer learning in which students provide feedback on each other's assignments. For example, for a writing assignment, students can provide feedback on each other's paper for technical details, such as adherence to style guidelines (e.g., MLA or APA) and proper use of class content. This type of peer learning would help student develop their technical skills and reduce the workload of the grader. Through using these forms of peer learning, students can have more meaningful educational experiences. The lists below suggest how peer learning can improve higher education.

Peer learning is a way to provide low-cost instruction for classes by

- Lightening the grading load of the instruction while providing more opportunities for students to practice applying what they have learned as long students are advanced

enough to provide feedback and not be cognitively overloaded (Ching & Hsu, 2013; Fox, 2013; Sadler & Good, 2006)
- Serving as effective moderators or facilitators for online discussions (Xie et al., 2014; Barkley, 2009; Rourke & Anderson, 2002)
- Learning sections of content independently and teach each other (Goldschmid & Goldschmid, 1976)
- Increasing the amount of feedback to support formative assessment (Black & Wiliam, 1998; Ching & Hsu, 2013)
- Participating in discussions that provide students different perspectives and help them to understand concepts more deeply (Bruffee, 1993)
- Reducing workload of the instructors by taking over duties such as lecturing, grading, etc. (Barkley, 2009; Goldschmid & Goldschmid, 1976)

Peer learning enables different types of learning experiences by

- Working in groups to solve large problems or work on projects (Khan, 2012; Goldschmid & Goldschmid, 1976)
- Providing opportunities to tutor and be tutored by other students (Khan, 2012; Goldschmid & Goldschmid, 1976)
- Crowdsourcing solutions to problems (Kim et al., 2013)

Peers provide social support by

- Holding each other accountable and supporting each other (Barkley, 2009; Goldschmid & Goldschmid, 1976)
- Increasing student motivation through social pressure (Barkley, 2009)
- Forming student groups that monitor each other's understanding and increase the pedagogical support that students receive in a class (Carrier & Sales, 1987)
- Working through concepts with someone with a similar level of knowledge (Crouch & Mazur, 2001)

Drawbacks of Peers

- Not seen as trustworthy or valuable sources of information (Goldschmid & Goldschmid, 1976)
- Providing feedback to peers can place too much cognitive load on students and impede their learning (Ching & Hsu, 2013)

The Strengths of Instructors

Someday technology might be able to completely replace instructors without meaningfully reducing learning outcomes, but if that is possible, we are a long way from it. Today's technology, however, can have a large impact on the role that instructors have in education. By using technology to deliver some instruction (particularly lectures), instructors have been able to transition from a lecturer who dispenses knowledge (referred to as "sage on the stage") to a facilitator who supports learning (referred to as "guide on the side"). This type of course is commonly called a blended course, and it is becoming popular in STEM domains. By taking the facilitator role, instructors can encourage students to take more responsibility for their learning while still providing insightful guidance that improves learning outcomes.

Some institutes have adopted an emporium model of instruction in which students taking an array of courses (typically in math) come to a learning center at a time that is convenient for them. In the learning center, students use computers to receive instruction and practice applying content. In this environment if students need help, then they can ask for it from the instructors that are on staff. In this model, because multiple instructors are available to help students, students can get different perspectives on the same question. In the emporium model in which students have access to practically unlimited technologically-support instruction, the ability of instructors to provide dynamic feedback and help to students is still a key component of education. The lists below suggest how instructors improve learning outcomes in higher education.

Instructors can provide high quality feedback and remediation to students

- Grading for style and content (Fox, 2013)
- Supporting formative assessment (Black & Wiliam, 1998)
- Providing remediation/tutoring (Khan, 2012; Williams, 2005)

Instructors can help develop professional and personal skills to reach goals

- Teaching skills like how to give a presentation (Ellmore et al., 1995; Yang, 2012)
- Mentoring (Khan, 2012)
- Helping students navigate resources made available by technology (Ellmore et al., 1995)
- Providing suitable support to individual learners and goals (e.g., higher commitment to learning and higher confidence needs less support; Knowles et al., 2011)
- Encouraging students to think critically about information (Ellmore et al., 1995)

Instructors can dynamically support students

- Facilitating learning (Knowles et al., 2011)
- Providing nonverbal communication during instruction (Walsh, 2011)

- Helping students stay focused and motivated by being flexible and picking up on social cues (Ellmore et al., 1995; Khan, 2012) which is important for engagement (Barkley, 2009)
- Personalizing social interaction with the goal of learning (i.e., rather than other goals peers might have like acceptance; Barkley, 2009)
- Teaching content and skills classified in the higher levels of Bloom's taxonomy, such as concepts and application of knowledge to problems (Nielsen, 2011)
- Providing prospective on how things relate or why they are important (Khan, 2012)

Drawbacks of Instructors

- Need training and experience in domain and education to be effective
- Are expensive with limited resources to invest in individual students

Conclusion

Both technology and peer learning have strengths in higher education. As we move forward in education, especially if it will be at scale, we should use both to produce a high quality experience while not increasing the demands of the instructor. The role of the instructor in large-scale courses also needs re-evaluation. We should consider how we can integrate these three sources of support to maximize the efficacy of education while still (or better) utilizing the unique skills of each. Below are predictions for how these sources might be integrated best based on each of their strengths. These predictions are not directly supported by research.

Predictions for optimal blends

- Delivering content
    - Basic course content: Technology should be used to initially deliver content to students to give students exposure to content at a location, time, and pace of their choosing.
    - Advanced course content: For content that is particularly difficult to understand or conceptual, content should be delivered in a learning environment with easy access to an instructor and/or peers to allow students to ask questions and discuss ideas.
- Applying content
    - Recurrent skills: Technology should be used to practice recurrent skills (i.e., skills that are applied the same way each time), such as vocabulary drills in a language class.
    - Non-recurrent skills: Peers and instructors should help students practice non-recurrent skills (i.e., skills that change with different applications), such as problem solving. Peers can also form groups to allow students to work on large projects or problems.
    - Simulations: Technology and peers can support simulations (e.g., foreign language conversation) that are low-risk (ungraded, practiced individually). Instructors can also support simulations, but they are typically high risk.
    - Discussion: Peers can play the role of discussant and/or moderator in discussions to explore ideas and argue different viewpoints.
- Assessing knowledge and providing feedback
    - Formulaic grading: Technology should be used for grading when using a formulaic answer key or rubric is appropriate.
    - Content grading: Peers can determine if the content of an answer is correct, especially if they are given a detailed rubric.
    - Stylistic grading: Instructors are best at grading the style of a response and determining if they match domain standards.
    - Formative feedback: Technology could be used to keep learners on track to the correct answer during problem solving (e.g., as intelligent tutors do). Peers could

deliver lower-order formative feedback, such as that employed in Peer Instruction. Instructors are necessary to provide integrative formative feedback that considers the state of knowledge of the learner and the state of knowledge in the field.

Questions for Future Research

- Would interaction with a virtual agent be as motivating as interaction with an instructor?
- How do we optimally change instruction based on knowledge level of learner (i.e., maintaining an optimal challenge zone; Barkley, 2009)?
- How do we identify gaps in prior and learned knowledge?
- For large groups of students, should they be placed in cohorts or free to find their own groups?
    - If placed in cohorts, should cohorts be by area of interest or with various interdisciplinary people?

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